University at Buffalo
Department of Computer Science and and Engineering
CSE 573 - Computer Vision and Image Processing

Fall 2023

Bonus Home Work
Due Date: 12/12/23, 11:59PM

1 Filter Design (10 points)

Design a 5x5 filter which can shift image up by 1 pixel and to the right by 2 pixels.

2 Gaussian Filter Separability (20 points)

One of the characteristics of Gaussian filter is that a 2D filter can be expressed as the product of two 1D Gaussian filters. Please express the following 2D 5x5 Gaussian filter as the product of two 1D Gaussian filters.

$$G = \frac{1}{100}\begin{pmatrix} 1 & 2 & 4 & 2 & 1 \\ 2 & 4 & 8 & 4 & 2 \\ 4 & 8 & 16 & 8 & 4 \\ 2 & 4 & 8 & 4 & 2 \\ 1 & 2 & 4 & 2 & 1 \end{pmatrix}$$

Provide an example that demonstrates your answer is accurate.

3 Harris Detector (40 points)

In Harris Corner Detection, it aims to find the difference in intensity for a displacement of (u, v) for all directions:$E(u,v) = \begin{bmatrix} u & v \end{bmatrix} \mathbf{M} \begin{bmatrix} u \\ v \end{bmatrix}$, where $\mathbf{M} = \sum_{x,y} \mathbf{W}(x,y) \begin{bmatrix} \mathbf{I}_X^2(x,y) & \mathbf{I}_X(x,y)\mathbf{I}_Y(x,y) \\ \mathbf{I}_X(x,y)\mathbf{I}_Y(x,y) & \mathbf{I}_Y^2(x,y) \end{bmatrix}$, and $\mathbf{W}$ is the window matrix. Assume that $\mathbf{W} = \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}$, $\mathbf{I}_X = \begin{bmatrix} 0 & 0 \\ 1 & 2 \end{bmatrix}$, and $\mathbf{I}_Y = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$. We use threshold f to determine whether the window contains a corner, where $f = \frac{\lambda 1 \lambda 2}{\lambda 1 + \lambda 2}$, $\lambda 1, \lambda 2$ are the eigen values of $\mathbf{M}$. If $f > 1$, we determine that the window contains a corner; otherwise, it does not contain a corner. 1. Calculate $\mathbf{M}$. (10 points)

2. Calculate $\lambda 1, \lambda 2$. (10 points)
3. Calculate f. (10 points)
4. Does this window contain a corner or not? (10 points)

4 Convolution (10 points)

Suppose we have an input image which is $\begin{pmatrix} 3 & 1 & 2 \\ 1 & 2 & 1 \\ 2 & 1 & 1 \end{pmatrix}$ and a convolution kernel which is $\begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \end{pmatrix}$

Assume we set stride as 1 and padding as 0 (no padding), determine the output of the convolution.

5 Template Matching (20 points)

26	3	184	75	80	128	72	0	84
89	65	0	200	224	18	170	26	54
47	75	127	52	94	26	68	43	199
81	87	86	0	97	3	9	208	218
23	12	188	176	180	1	2	6	3
0	80	54	39	31	22	40	9	2
5	21	9	12	98	176	211	105	9

3	10	20
18	1	5
2	30	3

Figure 1: Left: gray scale values of a 7×9 image. Right: gray scale values of a 3×3 template.

As shown in Figure 1, we have an image and a template. To determine which one of the three positions in the image indicated by the shaded pixels best matches the template, we can use either Sum of squared difference (SSD) or Normalized cross correlation (NCC). Do zero padding at the border if necessary.

1. Compute the sum of squared difference (SSD) at the three positions indicated by the shaded pixels. Explain which position is the best match. (10 points)

2. Compute the normalized cross correlation (NCC) at the three positions indicated by the shaded pixels. Explain which position is the best match. (10 points)

Instructions

- Answer the questions above, and provide as much of your work as necessary.

- Export or scan your homework and store it as a PDF version 'YourUBITName.zip' before submitting online to UBLearns.